MTB 099-74

REPORT
ON
RELATIVE CORROSIVITY OF ATMOSPHERES
AT VARIOUS DISTANCES FROM THE SEACOAST

PREPARED BY:

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NASA
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KENNEDY SPACE CENTER, FLORIDA 32899
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SUBJECT: Relative Corrosivity of Atmospheres at Various Distances from the Seacoast

1.0 FOREWORD

1.1 This is the summary report of an in-house investigative program initiated by William J. Paton in 1975 and continued by this organization after his reassignment. The purpose of this program was to obtain test data specifically to evaluate the effect of distance from the seacoast on the rate of corrosion of steel.

1.2 Most of the field corrosion tests perform-ed at KSC have utilized a single test site, located.along the Cape Road near the beach. The sample support racks are located about 100 to 120 feet from mean high tide. This is potentially a severe environment and has been used to simulate "wors t case" field exposure of ground support equipment (GSE) and to give a somewhat accelerated evaluation of candidate protective coatings for CSE. For example, zinc-rich coatings for application to steel structures at KSC are required to protect steel test panels for 18 months at this site. However, subjective evaluation of the corrosion rate of steel structures and various test samples located at greater distances from the seacoast has indicated that the "distance" variable has a profound effect on corrosion rate. It has also been noted that atmospheric effects, such as the prolonged easterly winds of early autumn, and the higher rainfall rates and higher relative humidities of summer, have distinct seasonal effects on corrosion rate.

1.3 Although these factors affecting corrosion rate could influence the corrosion protection methods selected for a given installation, no test data were available for the "distance effect" or for the variations in corrosion resulting from the prevailing weather conditions when exposure was initiated.

2.0 TEST PROCEDURES

This program was designed to obtain such data, by means of the following corrosion exposure tests.

2.1 Two types of test materials were used: AISI 1008 steel, and AISI 4130 steel. The former is a mild steel containing nominally 0.08% carbon and 0.40% manganese. The 4130 is a low alloy steel, used widely for aircraft applications, containing nominally 0.40% carbon, 0.50% manganese, 0.30% silicon, 1.0% chromium, and 0.20% molybdenum. With its content of alloying elements, it would be expected to be somewhat more resistant to atmospheric corrosion than the 1008 steel. The test samples were 4" X 6" X 1/8" panels of the two steels, as received in the hot-rolled condition. A thin layer of mill scale was present on the samples. These samples were weighed to the nearest 0.01 gram prior to testing.

2.2 Six corrosion test sites, at various distances from the ocean, were utilized: No. 1 (beach) 100 feet; No. 2 (near Complex 41 entrance) 800 feet; No. 3 (near perimeter fence, east side of Complex 39A) 2500 feet; No. 4 (in yard of water pump station, Pad B Road), 5,200 feet; No. 5 (behind Building M7-505, Industrial Area) 6 miles; and No. 6 (Orlando Naval Training Center) 50 miles.

2.3 Five test panels of each material were placed in east-facing support racks at each exposure site every month for 23 months. After 12 months, the first group of 5 samples of each material was removed from each site and brought to the laboratory for analysis. The following month, the second group was removed. This process continued until all test groups at each site had been exposed for 12 months and then removed for evaluation.

3.0 RESULTS

3.1 The results of the 12 month exposure tests are presented in Tables 1 through 12, which give the weight loss from corrosion of the two test materials for each of the 23 exposure periods at each of the six exposure sites. These data are summarized in Table 13, in which the average weight loss over the entire test period is given for each test material at each corrosion test site. Figure 1 is a graphical presentation of these data, showing weight loss as a function of distance from the seacoast for the two test materials. The average weight loss data (from Table 13) are plotted, and the weight-loss envelopes (maximum and minimum losses) are also shown. The data presented in Table 13 and Figure 1 are those accummulated during the entire test period from April, 1975 through February, 1978.

3.2 At the 100-foot site (beach), the AISI 1008 steel corroded at a considerably higher rate than the AISI 4130 (approximately 3 1/2 times, based on average data for the entire program interval). At the 800-foot site the rate differential for the two steels decreased to about 2:1, and, at greater distances from the seacoast, the corrosion rate differential continued to decrease slightly. For the AISI 1008 steel, the corrosion rate at the 800-foot site was about 1 1/2 times that at the 50-mile site, a relatively minor rate differential for such a large increase in distance from the seacoast. The differential for the AISI 4130 steel was even less: 6.6 grams at the 800-foot site versus 5.4 grams for the 50-mile site.

3.3 As is shown in Figure 1, the weight-loss data envelope for the AISI 1008 steel exposed at the 100-foot site is very wide, varying by a factor of 3. This indicated a pronounced effect of seasonal variations in atmospheric conditions during the various exposure periods at the beach site. The envelope is much narrower for the AISI 4130 steel at the 100-foot site, and is relatively narrow for both steels at the 800-foot site and all sites more remote from the seacoast.

3.4 This effect of seasonal variations in weather phenomena on corrosion rate at the 100-foot site is shown in Figure 2, in which weight losses for the two steels are plotted for sample groups representing each of the 23 exposure periods. There is a general increase in weight loss for the AISI 1008 steel after the third exposure period (samples placed at the beach site in June 1975). This weight loss peaked with the eleventh exposure-period samples (those exposed beginning in February, 1976). Weight losses dropped thereafter, reaching a minimum with the thirteenth group (exposed beginning April, 1976). This was followed by another increase in weight loss, which reached another peak with the nineteenth group (exposed beginning October, 1976). The mechanisms by which the combinations of meteorological factors contributing to these wide variations in corrosion rates operate, are not known. Since each of the 23 test groups remained at the 100-foot exposure site for 12 months, it might be expected that seasonal variations in these factors would largely be compensated for. It is possible that the determining factor may be the prevailing conditions immediately following placement of the samples at the Beach Site. Certainly, high humidity, air-borne salt, and warm temperatures would be expected to result in a high corrosion rate. If these conditions prevail from the start of exposure, the samples may rapidly develop a thick layer of iron corrosion product, which is loosely adherent and moisture absorbing. Consequently, this initial corrosion layer may tend to accelerate, rather than prevent, further corrosion.

3.5 The role of air-borne sea salt has been cited, and is widely acknowledged, as the main factor in rapid corrosion of succeptible structural materials used near the seacoast. Recent studies were conducted at KSC by Management Services Incorporated, under TS direction, to determine the concentration of air-borne sodium chloride at different distances from the seacoast. Of seven sampling points used, six were the six corrosion exposure sites listed in Paragraph 2.2, above. The results of these studies were published in a technical report and two addendum reports ("Local Atmosphere Salt Profile" , Shuttle Study Task No. 0031, July 8, 1974; "Local Atmosphere Salt Profile - Addendum I", June 2, 1975; "Local Atmosphere Salt Profile - Addendum II", October, 1976). These studies showed considerable variations in atmospheric salt with prevailing wind direction, and, as would be expected, easterly winds produced the highest average salt concentration. It was also noted that samples taken during heavy fogs contained much higher concentration of salt than samples taken during clear conditions. These observations are significant to the noted variations of corrosion rate with seasonal weather changes. Of more obvious significance, however, are the data obtained for atmospheric salt concentrations at various distances from the sea coast, and the relationship of this factor to the corrosion rates of mild steel at the same locations.

Figure 3 shows graphically the variation in air-borne salt (collected by the funnel method) at the six corrosion exposure sites. The plotted values are averages of biweekly samples taken over a period from April, 1975, to November, 1976. The salt concentration is shown to be an exponential function of distance from the seacoast. (Refer to ordinate at left for units). It should be noted that the selection of ordinate'scales for these plots was arbitrary, and no quantitative relationship can be demonstrated. However, a similarity in curve shape for these two plots is evident, and the corrosion rate of the AISI 1008 steel is evidently also an exponential function of distance from the seacoast. These comparative data also demonstrate the controlling influence on corrosion rate of the atmospheric salt concentration.

4.0 CONCLUSIONS

4.1 The weight loss from atmospheric corrosion of AISI 1008 steel exposed at 6 test sites at various distances from the seacoast exceeded that of AISI 4130 steel exposed under similar conditions, The corrosion rate of the 1008 steel at a site 100 feet from the ocean was greater by a factor of 3 than was the corrosion rate of the 4130 steel. At sites more remote from the coast (800 feet to 50 miles), the corrosion rate differential between the two steels was less but was significantly greater for the 1008.

4.2 Variations in corrosion rates, particularly for the AISI 1008 steel at the 100-foot site (beach), were demonstrated with samples placed at the test site each month for 23 months and exposed for a 12-month period. Variations in weight loss by a factor of 3, depending upon the period of exposure, were noted. It is believed that this phenomenon is caused by a complex interrelationship among prevailing winds, humidity, and rainfall.

4.3 Corrosion rates for the AISI 1008 steel were found to be an exponentional function of distance from the seacoast. It is noted that salt content in the KSC area atmospherehas also been shown to be an exponential function of distance from the seacoast, and it is believed that the corrosion rate of the steel is largely inflUenced by this relationship.

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TABLE 1

AISI 1008 STEEL SAMPLES

EXPOSED AT BEACH (100 FOOT) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	35.1
2.	May '75 - May '76	36.2
3.	June '75 - June '76	35.6
4.	July '75 - July '76	53.1
5.	August '75 - August '76	47.7
6.	September '75 - September '76	70.5
7.	October '75 - October '76	63.7
8.	November '75 - November '76	64.9
9.	December '75 - December '76	69.0
10.	January '76 - January '77	90.1
11.	February '76 - February '77	95.1
12.	March '76 - March '77	74.4
13.	April '76 - April '77	33.9
14.	May '76 - May '77	42.8
15.	June '76 - June '77	49.6
16.	July '76 - July '77	72.9
17.	August '76 - August '77	82.7
18.	September '76 - September '77	79.9
19.	October '76 - October '77	87.1
20.	November '76 - November '77	62.3
21.	December '76 - December '77	47.9
22.	January '77 - January '78	54.6
23.	February '77 - February '78	56.4
	AVERAGE	61.1

TABLE 2

AISI 4130 STEEL SAMPLES

EXPOSED AT BEACH (100 FOOT) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS CRAMS
1.	April '75 - April '76	11.8
2.	May '75 - May '76	18.3
3.	June '75 - June '76	17.2
4.	July '75 - July '76	16.5
5.	August"75 - August '76	13.2
6.	September '75 - September '76	13.6
7.	October '75 - October '76	12.9
8.	November '75 - November '76	13.7
9.	December '75 - December '76	14.4
10.	January '76 - January '77	17.3
11.	February '76 - February '77	21.1
12.	March '76 - March '77	13.9
13.	April '76 - April '77	12.0
14.	May '76 - May '77	19.3
15.	June '76 - June '77	20.4
16.	July '76 - July '77	17.2
17.	August '76 - August '77	19.7
18.	September '76 - September '77	19.6
19.	October '76 - October '77	18.5
20.	November '76 - November '77	27.7
21.	December '76 - December '77	17.3
22.	January '77 - January '78	14.7
23.	February '77 - February '78	10.2
	AVEMCE	16.9

TABLE 3

AISI 1008 STEEL SAMPLES

EXPOSED AT COMPLEX 41 (800 FOOT) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	9.5
2.	May '75 - May '76	10.1
3.	June '75 - June '76	10.0
4.	July '75 - July '76	9.9
5.	August '75 - August '76	11.3
6.	September '75 - September '76	11.8
7.	October '75 - October '76	12.1
8.	November '75 - November '76	12.0
9.	December '75 - December '76	14.1
10.	January '76 - January '77	12.0
11.	February '76 - February '77	11.9
12.	March '76 - March '77	11.5
13.	April '76 - April '77	8.9
14.	May '76 - May '77	11.3
15.	June '76 - June '77	13.0
16.	July '76 - July '77	11.6
17.	August '76 - August '77	13.5
18.	September '76 - September '77	13.5
19.	October '76 - October '77	12.3
20.	November '76 - November '77	12.8
21.	December '76 - December '77	12.1
22.	January '77 - January '78	10.7
23.	February '77 - February '78	10.5
	AVERAGE	11.6

TABLE 4

AISI 4130 STEEL SAMPLES

EXPOSED AT COMPLEX 41 (800 FOOT) TEST.SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	4.3
2.	May '75 - May '76	5.7
3.	June '75 - June '76	5.2
4.	July '75 - July '76	5.6
5.	August,'75 - August '76	6.0
6.	September '75 - September '76	6.5
7.	October '75 - October '76	7.1
8.	November '75 - November '76	6.8
9.	December '75 - December '76	8.5
10.	January '76 - January '77	6.9
11.	February '76 - February '77	6.6
12.	March '76 - March '77	7.7
13.	April '76 - April '77	3.2
14.	May '76 - May '77	7.5
15.	June '76 - June '77	7.5
16.	July '76 - July '77	7.0
17.	August '76 - August '77	9.0
18.	September '76 - September '77	6.4
19.	October '76 - October '77	6.1
20.	November '76 - November '77	8.7
21.	December '76 - December '77	7.2
22.	January '77 - January '78	5.7
23.	February '77 - February '78	5.7
	AVERAGE	6.6

TABLE 5

AISI 1008 STEEL SAMPLES

EXPOSED AT COMPLEX 39A (2500 FOOT) TEST. SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	9.4
2.	May '75 - May '76	10.2
3.	June '75 - June '76	9.7
4.	July '75 - July '76	9.1
5.	August '75 - August '76	10.9
6.	September '75 - September '76	12.5
7.	October '75 - October '76	12.5
8.	November '75 - November '76	12.1
9.	December '75 - December '76	12.3
10.	January '76 - January '77	12.1
11.	February '76 - February '77	12.3
12.	March '76 - March '77	12.0
13.	April '76 - April '77	7.3
14.	May '76 - May '77	10.9
15.	June '76 - June '77	13.5
16.	July '76 - July '77	11.5
17.	August '76 - August '77	13.5
18.	September '76 - September '77	13.7
19.	October '76 - October '77	13.0
20.	November '76 - November '77	13.0
21.	December '76 - December '77	11.5
22.	January '77 - January '78	10.6
23.	February '77 - February '78	9.5
	AVERAGE	11.4

TABLE 6

AISI 4130 STEEL SAMPLES

EXPOSED AT COMPLEX 39A (2500 FOOT) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	5.0
2.	May '75 - May '76	5.9
3.	June '75 - June '76	3.7
4.	July '75 - July '76	5.5
5.	August"75 - August '76	5.6
6.	September '75 - September '76	8.0
7.	October '75 - October '76	9.1
8.	November '75 - November '76	7.1
9.	December '75 - December '76	6.6
10.	January '76 - January '77	7.3
11.	February '76 - February '77	7.0
12.	March '76 - March '77	7.3
13.	April '76 - April '77	3.1
14.	May '76 - May '77	6.8
15.	June '76 - June '77	7.6
16.	July '76 - July '77	7.0
17.	August '76 - August '77	8.1
18.	September '76 - September '77	8.2
19.	October '76 - October '77	5.9
20.	November '76 - November '77	8.5
21.	December '76 - December '77	7.6
22.	January '77 - January '78	5.7
23.	February '77 - February '78	4.9
	AVERAGE	6.6

TABLE 7

AISI 1008 STEEL SAMPLES

EXPOSED AT PUMP HOUSE (5200 FOOT) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	6.9
2.	May '75 - May '76	7.9
3.	June '75 - June '76	6.6
4.	July '75 - July '76	6.5
5.	August '75 - August '76	8.1
6.	September '75 - September '76	9.2
7.	October '75 - October '76	10.5
8.	November '75 - November '76	9.3
9.	December '75 - December '76	8.7
10.	January '76 - January '77	9.4
11.	February '76 - February '77	8.7
12.	March '76 - March '77	8.4
13.	April '76 - April '77	5.3
14.	May '76 - May '77	8.6
15.	June '76 - June '77	9.9
16.	July '76 - July '77	9.2
17.	August '76 - August '77	9.5
18.	September '76 --September '77	10.5
19.	October '76 - October '77	10.7
20.	November '76 - November '77	9.7
21.	December '76 - December '77	9.3
22.	January '77 - January '78	9.4
23.	February '77 - February '78	8.0
	AVERAGE	8.7

TABLE 8

AISI 4130 STEEL SAMPLES

EXPOSED AT PUMP HOUSE (5200 FOOT) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	3.9
2.	May '75 - May '76	4.7
3.	June '75 - June '76	3.3
4.	July '75 - July '76	3.6
5.	August '75 - August '76	4.9
6.	September '75 - September '76	6.1
7.	October '75 - October '76	7.8
8.	November '75 - November '76	5.9
9.	December '75 - December '76	5.5
10.	January '76 - January '77	5.5
11.	February '76 - February '77	4.9
12.	March '76 - March '77	5.9
13.	April '76 - April '77	1.7
14.	May '76 - May '77	5.3
15.	June '76 - June '77	5.8
16.	July '7.6 - July '77	5.4
17.	August '76 - August '77	6.2
18.	September '76 - September '77	6.2
19.	October '76 - October '77	4.9
20.	November '76 - November '77	6.5
21.	December '76 - December '77	6.0
22.	January '77 - January '78	4.3
23.	February '77 - February '78	4.7
	AVERAGE	5.2

TABLE 9

AISI 1008 STEEL SAMPLES

EXPOSED AT INDUSTRIAL AREA (6 MILE) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	8.1
2.	May '75 - May '76	8.1
3.	June '75 - June '76	6.9
4.	July '75 - July '76	7.6
5.	August '75 - August '76	7.7
6.	September '75 - September '76	9.0
7.	October '75 - October '76	8.5
8.	November '75 - November '76	8.9
9.	December '75 - December '76	9.2
10.	January '76 - January '77	9.2
11.	February '76 - February '77	8.9
12.	March '76 - March '77	7.6
13.	April '76 - April '77	6.3
14.	May '76 - May '77	8.0
15.	June '76 - June '77	9.2
16.	July '76 - July '77	8.6
17.	August '76 - August '77	9.2
18.	September '76 - September '77	10.9
19.	October '76 - October '77	10.8
20.	November '76 - November '77	9.7
21.	December '76 - December '77	8.9
22.	January '77 - January '78	9.9
23.	February '77 - February '78	8.4
	AVERAGE	8.7

TABLE 10

AISI 4130 STEEL SAMPLE

EXPOSED AT INDUSTRIAL AREA (6 MILE) TEST'SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	5.1
2.	May '75 - May '76	5.1
3.	June '75 - June '76	4.3
4.	July '75 - July '76	4.1
5.	August"75 - August '76	5.0
6.	September '75 - September '76	6.1
7.	October '75 - October '76	6.0
8.	November '75 - November '76	6.3
9.	December '75 - December '76	5.8
10.	January '76 - January '77	5.1
11.	February '76 - February '77	6.4
12.	March '76 - March '77	5.5
13.	April '76 - April '77	1.6
14;	May '76 - May '77	4.8
15.	June '76 - June '77	6.0
16.	July '76 - July '77	5.6
17.	August '76 - August '77	6.6
18.	September '76 - September '77	7.6
19.	October '76 - October '77	7.3
20.	November '76 - November '77	6.9
21.	December '76 - December '77	6.4
22.	January '77 - January '78	4.3
23.	February '77 - February '78	5.2
	AVERAGE	5.5

TABLE 11

AISI 1008 STEEL SAMPLES

EXPOSED AT ORLANDO (50 MILE) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS GRAMS
1.	April '75 - April '76	6.9
2.	May '75 - May '76	7.5.
3.	June '75 - June '76	6.5
4.	July '75 - July '76	5.9
5.	August '75 - August '76	7.4
6.	September '75 - September '76	8.3
7.	October '75 - October '76	7.7
8.	November '75 - November '76	7.6
9.	December '75 - December '76	10.9
10.	January '76 - January '77	7.1
11.	February '76 - February '77	7.3
12.	March '76 - March '77	6.8
13.	April '76 - April '77	4.4
14..	May '76 - May '77	7.1
15.	June '76 - June '77	8.5
16.	July '76 - July '77	7.5
17.	August '76 - August '77	8.2
18.	September '76 - September '77	9.7
19.	October '76 - October '77	6.9
20.	November '76 - November '77	8.9
21.	December '76 - December '77	8.7
22.	January '77 - January '78	8.7
23.	February '77 - February '78	7.3
	AVERAGE	7.6

TABLE 12

AISI 4130 STEEL SAMPLES

EXPOSED AT ORLANDO (50 MILE) TEST SITE

	EXPOSURE PERIOD	WEIGHT LOSS, GRAMS
1.	April '75 - April '76	4.7
2.	May '75 - May '76	4.9
3.	June '75 - June '76	4.7
4.	July '75 - July '76	4.1
5.	August '75 - August '76	5.0
6.	September '75 - September '76	6.3
7.	October '75 - October '76	5.8
8.	November '75 - November '76	5.8
9.	December '75 - December '76	7.4
10.	January '76 - January '77	4.5
11.	February '76 - February '77	5.0
12.	March '76 - March '77	5.7
13.	April '76 - April '77	2.8
14.	May '76 - May '77	4.5
15.	June '76 - June '77	6.5
16.	July '76 - July '77	4.6
17.	August '76 - August '77	6.3
18.	September '76 - September '77	7.3
19.	October '76 - October '77	4.8
20.	November '76 - November '77	6.3
21.	December '76 - December '77	6.9
22.	January '77 - January '78	6.0
23.	February '77 - February '78	4.0
	AVERAGE	5.4

TABLE 13 .

AVERAGE WEIGHT LOSS FOR ALL EXPOSURE PERIODS

CORROSION TEST SITE	DISTANCE FROM SEACOAST	WEIGHT LOSS, GRAMS — TEST MATERIAL AISI 1008	AISI 4130
1	100 feet	61.1	'16.9
2	800 feet	11.6	6.6
3	2500 feet	11.4	6.6
4	5200 feet	8.7	5.2
5	6 miles	8.7	5.5
6	50 miles	7.6	5.4

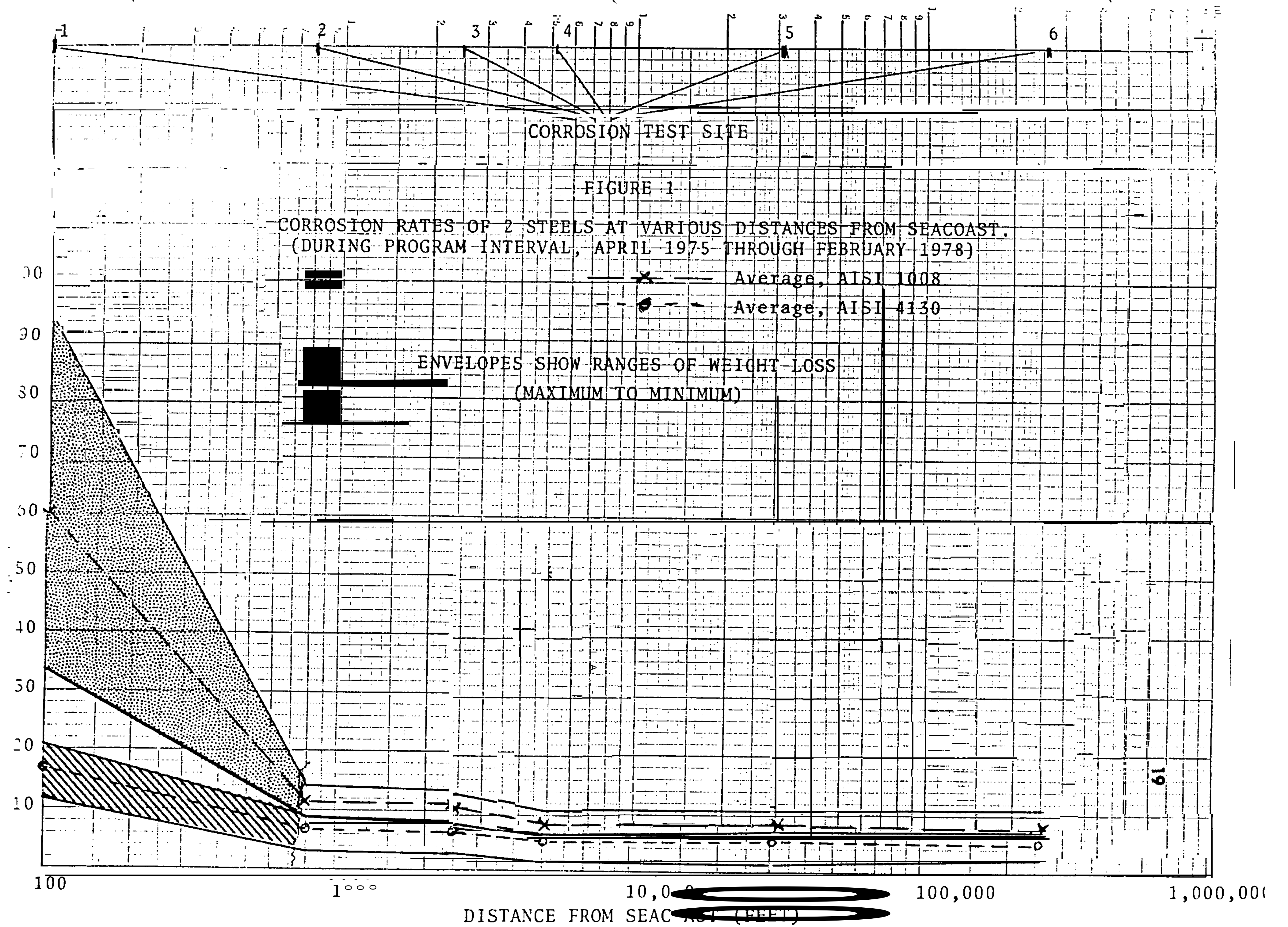


FIGURE 1

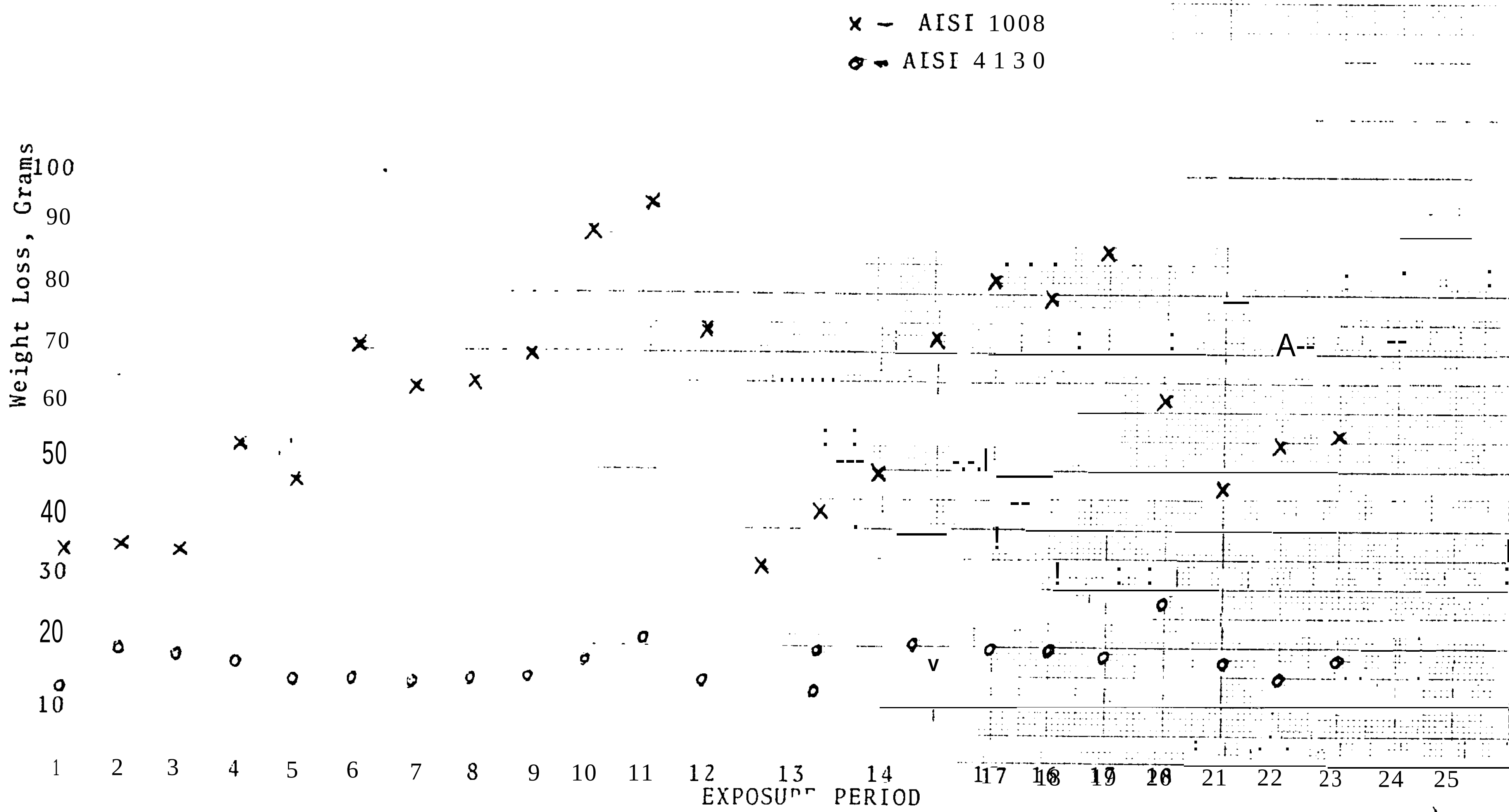
CORROSION RATES OF 2 STEELS AT VARIOUS DISTANCES FROM SEACOAST.
(DURING PROGRAM INTERVAL, APRIL 1975 THROUGH FEBRUARY 1978)

FIGURE 2

CORROSION RATES FOR 2 STEELS EXPOSED AT BEACH (100 FT) SITE

FOR 1 YEAR, DURING PROGRAM INTERVAL,

APRIL 1975 THROUGH FEBRUARY 1978.



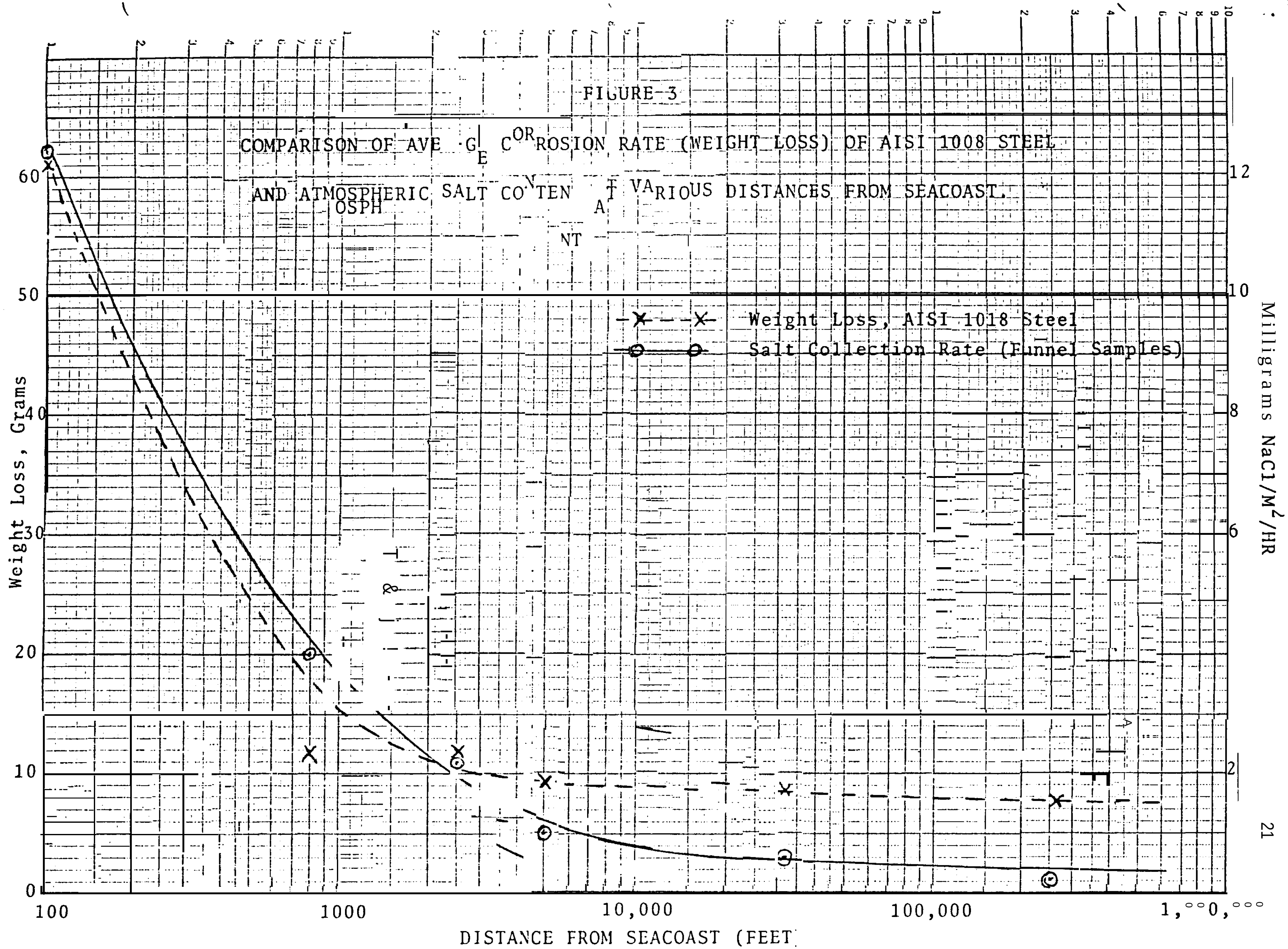


FIGURE 3
COMPARISON OF AVERAGE CORROSION RATE (WEIGHT LOSS) OF AISI 1008 STEEL
AND ATMOSPHERIC SALT CONTENT AT VARIOUS DISTANCES FROM SEACOAST.
Weight Loss, AISI 1018 Steel
Salt Collection Rate (Funnel Samples)
Weight Loss, Grams
0
10
20
30
40
50
60
Milligrams NaCl/M²/HR
2
6
8
10
12
100
1000
10,000
100,000
1,000,000
DISTANCE FROM SEACOAST (FEET)